

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



# Pollution and Air Quality in Târgoviște Municipality and Its Surroundings (Romania)

Pehoiu Gica and Murărescu Ovidiu  
*"Valahia" University of Târgoviște*  
 Romania

## 1. Introduction

Târgoviște Municipality is situated in the High Plain of Târgoviște, at an average absolute altitude of 280 m. The town has an administrative area of 4,681 ha, in which the constructible area includes 1,966 ha; within the latter, 100.7 ha represent green area (Fig.1).

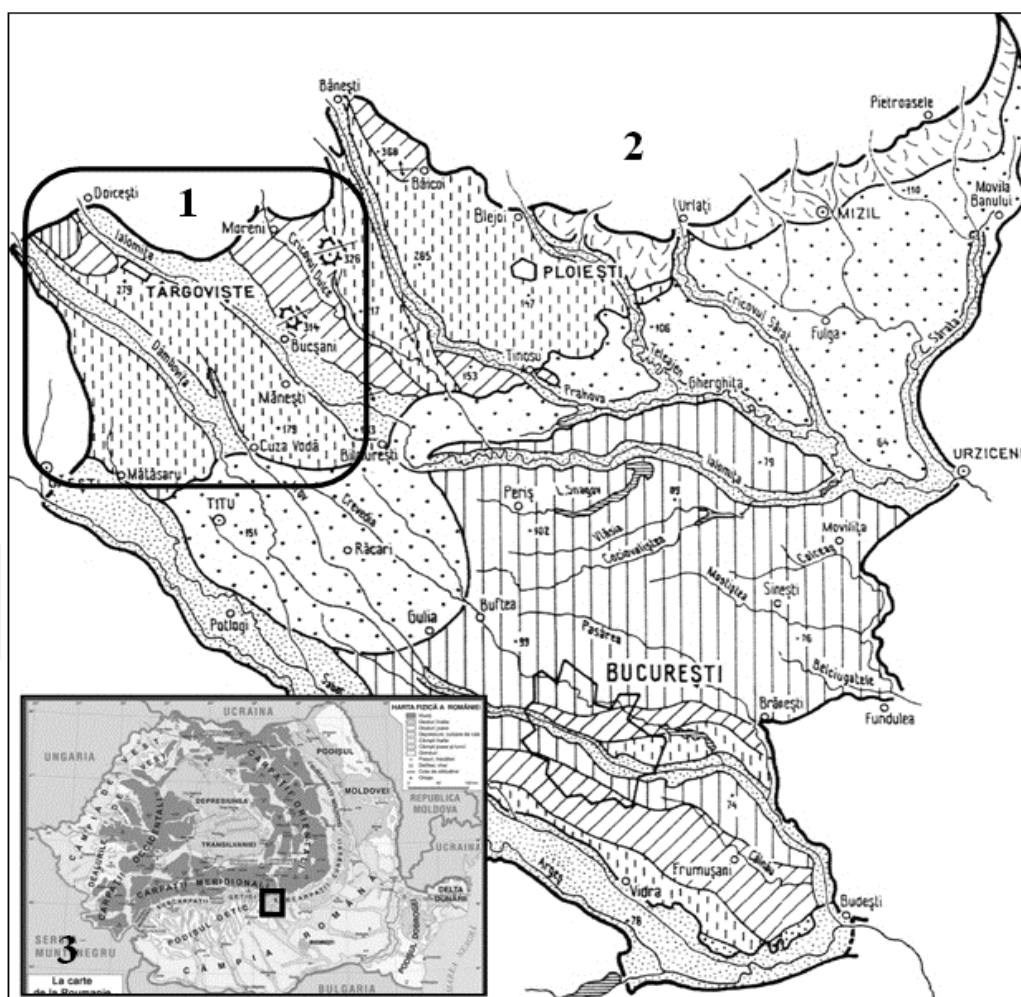


Fig. 1. Geographical position of Târgoviște Plain (1) in Ialomița Plain (2) and Romania (3).

Târgoviște had a population of 88,119 inhabitants in the year 2010 - representing 54.06% of the total urban population of Dâmbovița County and 16.63% of the total population of the county -, the density of the town's population being of 1,882.4 inhabitants/km<sup>2</sup> (Statistical Yearbook of Dâmbovița County, 2010).

This old industrial center has developed and diversified concomitantly to the general development of the economy (after the year 1968, on the occasion of the new administrative-territorial division, Târgoviște became political-administrative center of the county). It is during this period that the industrial platform, with several economic units and new branches appeared, completing the town's industrial profile; this profile has undergone significant changes after the year 1990. Here, at present, there are nationally important industrial units, on the platform situated in the south-west of the town. They actually represent the main sources with a potential impact on the air quality in Târgoviște municipality and its neighborhood. Among these, one can mention: SC Mechel SA, in the metallurgical domain, producing special steels, SC Upet SA (now being restructured), SC Nemo SA, focused on machine building, SC Swarco - Vicas SA, producing paints and varnish, SC Oțel Inox SA, laminating steels, SC Cromsteel SA, a company based on chroming processes, SC Romlux SA, an industrial unit producing light fixtures and others (Pehoiu, 2003; Pehoiu et al., 2005).

Doicești commune is situated near Târgoviște municipality; this commune also holds some industrial units, of which Uzina Electrică (the Power Station), using black oil and brown coal as fuels to generate electricity, SC Nubiola România SRL, a company producing whiteners and green chrome oxide - SO<sub>2</sub> and possibly a sulfuretted hydrogen source in the process of sulphur combustion needed to obtain ultramarine -, SC Soceram SA, a company producing bricks and ceramic materials.

Fieni Town, situated in the north of the political-administrative center of Dâmbovița County, is remarkable through its industrial units: SC Carpatcement Holding SA, a producer of building materials (cement) and SC Carmeuse Holding SRL (lime producer), which represent the main sources of environmental degradation for the locality of Fieni and its surroundings (Pehoiu, 2008).

Târgoviște Town is a significant consumer of resources and at the same time a major producer of polluting emissions, resulting mainly from: industrial activity, intensification of road traffic and generation of high quantities of waste.

## 2. Working methodology

In order to analyze the air quality status and the effects of the air pollution in a mainly industrial town that has gone through important structural modifications after 1990, when we analyzed the pollutants' dispersion, we took into account as well the role of the climatic factors (wind - its speed and directions, atmospheric humidity, atmospheric calm, hydrometeors - fog, air temperature).

The air analysis network component pertaining to Dâmbovița County is managed by the Departmental Agency for Environmental Protection - AEP (Agenția Județeană pentru Protecția Mediului) and includes fixed monitoring stations in the localities Târgoviște (Fig. 2) and Fieni (an automatic station each), and one in Doicești, with manual sampling of the pollutants and analysis in the laboratory, by means of which the specialists monitor the

concentrations of the dusts in suspension and of the gaseous pollutants (ammonia, nitrogen oxides, sulphur dioxide, sulphuretted hydrogen, formaldehyde).



Fig. 2. Map of the air monitoring locations in Târgoviște municipality (AEP Târgoviște).

At present, the monitoring of the air quality in these points supposes the continual gathering of daily samples from the atmosphere (24 h), followed by the analysis of the samples in the laboratory. This kind of analysis allows to highlight the dangerous concentrations for the population's health in due time. The data obtained following the measurements serve to create databases and to elaborate reports or informative bulletins in the aftermath of the occurrence of eventual pollution episodes.

Excepting the meteorological parameters, a series of polluting indicators were monitored, such as: benzene, carbon monoxide, sulphur dioxide, nitrogen oxides, lead, heavy metals etc. These pollutants were gathered from several manual sampling points distributed around the town, including the residential and the industrial areas.

In order to determine the quantities of dusts and polluting emissions present in the atmosphere and influencing the air quality status, the polluting agents were separated depending on the area they influence (for instance, the dusts emitted in the atmosphere by a series of metallurgical companies are carried over two residential quarters in the south-east of the town).

Following the comparative analysis of the polluting components, during the last few years one can notice a slight improvement of the air quality compared to the previous period in point of dusts-caused pollution. In the areas in which they are monitored in the atmosphere, gaseous pollutants (nitrogen dioxide, sulphur dioxide, ammonia, sulphuretted hydrogen, formaldehyde, oxidant substances, and carbon monoxide) are not present in concentrations over the limits allowed by the present legislation.

The pollutants to be monitored, the measurement methods, the limit values (LV), the alert and information thresholds and the criteria for situating the monitoring points are established by the national legislation concerning the atmospheric protection, being in agreement with the demands of the European regulations.

The realizations concerning the development of the air quality monitoring network in Dâmbovița County during the period 2007-2010 consisted in:



- remodeling and adapting the environmental laboratories for the installation of new laboratory equipments; installing these equipments; instructing the personnel;
- completing the endowment of the automated air quality monitoring stations from Târgoviște and Fieni.

AEP Dâmbovița monitored the level of the dusts in suspension in the area of Târgoviște, by means of its four sampling stations. In the municipality, the indicator of breathable dusts was monitored in the PM<sub>10</sub> fraction in the quarter Micro XII (2 representative points for the dusts resulted from SC Mechel SA Târgoviște) and the Civic Center – representative for the dusts resulted from road traffic and other sources after dispersion (SC Mechel SA) – where the indicator monitored was that of total dusts in suspension.

### 3. Air quality

The air is the environmental factor constituting the most rapid support favoring the pollutants' transportation in the environment. Air pollution has many and significant negative effects on the population's health and may damage as well the flora and fauna in general.

Air quality depends on the emissions that end up in the air coming from stationary and mobile sources (road traffic), mainly in big cities, as well as on the pollutants' transport on longer distances.

The automated stations and the manual sampling points are situated in representative areas in point of pollution, in the localities mentioned, as follows:

- *Automated station DB-1*, situated in Târgoviște municipality, Vlad Țepeș Str., no. 6 C (in the courtyard of the Social Care Center "Sfânta Maria"), coordinates: 25°28'41.6"; 44°54'58.39";
- *Automated station DB-2*, situated in Fieni Town, Teilor Str., no. 20 (in the town's central park), coordinates: 25°25'18.30"; 45°07'52.98";
- *Fixed manual sampling point* in Târgoviște - PM<sub>10</sub> fraction, in the Micro XII station, point 1, Constructorilor Str., no. 21 (Procor headquarters, industrial platform);
- *Fixed manual sampling point* in Doicești (CFR Station) – gaseous pollutants (sulphur dioxide - SO<sub>2</sub>, nitrogen dioxide - NO<sub>2</sub>, sulphuretted hydrogen - H<sub>2</sub>S and hexavalent chromium – expressed as CrO<sub>3</sub>) and total dusts in suspension (TSP). The gaseous pollutants determinations in the point Doicești continue to be carried out in agreement with the analysis methods mentioned by STAS 12574/1987.

*Settleable dusts are monitored by means of measurements in six fixed points situated in the following locations:*

- Târgoviște - 3 sampling points – point 1 Micro XII, AEP headquarters, and Micro XI (DB-1 station);
- Doicești - 1 sampling point - CFR Train Station;
- Fieni - 2 sampling points - point 1 (Fieni Park) and point 2, DB-2 station.

#### 3.1 Atmospheric pollutants

- **Benzene**

*General features:*

- - Very light aromatic compound, volatile and water-soluble;
- - 90% of the benzene present in the air comes from road traffic;
- - The rest of 10% comes from fuel evaporation during its storage and distribution.

*Effects on health:* carcinogenic substance, classified into the A1 toxicity class, known as carcinogenic for man. It produces negative effects on the central nervous system.

*Measurement methods:* the method of reference for measuring benzene is that of sampling by aspiration into an absorbing cartridge, followed by gas-chromatographic determination, standardized at present by the European Committee for Standardization (CEN).

- **Carbon monoxide**

*General features.* At room temperature, carbon monoxide is a colorless, odorless, tasteless gas, of both natural and anthropic origin. Carbon monoxide is formed mainly through the incomplete burning of fossil fuels.

*Natural sources:* forest burning, volcanic emissions, electric discharges.

*Anthropic sources:* it is formed mainly through the incomplete burning of fossil fuels, steel and pig iron production, oil refinement, and road, air and railroad traffic.

Carbon monoxide can accumulate up to a dangerous level especially during the period of atmospheric calm during winter and spring (this gas being much more stable from a chemical viewpoint at low temperatures), when the burning of fossil fuels attains a maximum level. Produced by natural sources, it is very rapidly dispersed in a wide area, and consequently does not affect human health.

*Effects on people's health.* It is a toxic gas, being lethal in high concentrations (at concentrations of about 100 mg/m<sup>3</sup>) through the reduction of the blood's capacity to transport oxygen, with consequences on the respiratory and cardiovascular system.

At relatively low concentrations, it affects the central nervous system, weakens the pulse rate, diminishing the blood volume distributed in the organism, and at the same time it reduces visual acuity and physical capacity. Being exposed for a short period of time, one may experience acute fatigue. At the same time, it may trigger respiratory difficulties, chest pains in people with cardiovascular diseases, determining as well irritability, migraines, rapid respiration, lack of coordination, nausea, dizziness, confusion, and can reduce the ability to concentrate.

The population segments most affected by the exposure to carbon monoxide are represented by children, elderly, people with respiratory and cardiovascular diseases, anemic people and smokers.

*Effects on plants.* At concentrations normally encountered when monitoring the atmosphere, carbon monoxide does not affect the plants, the animals or the environment.

*Measurement methods:* the reference method for measuring carbon monoxide is the non-dispersive infrared (NDIR) spectrometric method: ISO 4224.

- **Sulphur dioxide**

*General features.* Sulphur dioxide is a colorless, bitter, non-flammable gas, with a penetrating odor that irritates the eyes and the respiratory system.

*Natural sources:* volcanic eruptions, marine phytoplankton, bacterial fermentation in the marshy areas, oxidation of the gas containing sulphur resulted from biomass decomposition.

*Anthropic sources:* population's heating systems, when the fuel used is not methane, thermoelectric power stations, industrial processes (siderurgy, refinery, sulfuric acid production), cellulose industry and, to a lesser extent, the emissions coming from diesel engines.

*Effects on people's health.* Depending on its concentration and the period of exposure, sulphur dioxide has different effects on human health. The exposure to a high concentration of sulphur dioxide during a short period of time can cause severe respiratory difficulties. Particularly affected are: people with asthma, children, elderly and people with chronic respiratory diseases. The exposure to a low concentration of sulphur dioxide for a long lapse of time can result in infections of the respiratory system. Sulphur dioxide can interfere with the dangerous effects of the ozone.

*Effects on plants.* Sulphur dioxide clearly affects many plant species, the negative effect on their structure and tissues being visible with the naked eye. Some of the most sensitive plants are: pine, vegetables, red and black acorns, white ash, lucerne, blackberries.

*Effects on the environment.* In the atmosphere, it contributes to the acidification of the precipitations, with toxic effects on the vegetation and on the soil. The increase of the sulphur dioxide concentration accelerates metals' corrosion, because of the formation of acids. Sulphur oxides can erode: stones, brick-and-mortar, paints, fibers, paper, skin and electric components.

*Measurement methods:* the standard sulphur dioxide analysis method is the one pointed out in ISO/FDIS 10498 (standard project) named "Aer înconjurător - determinarea dioxidului de sulf" ("Surrounding air - sulphur dioxide determination") - UV fluorescence method.

## • Ozone

*General features:* very oxidant, very reactive gas, with choking smell. It is concentrated in the stratosphere and assures our protection against the UV radiation, which is damaging for life. The ozone present on the soil level acts as a component of the "photochemical smog". It appears following a reaction that involves mainly nitrogen oxides and volatile organic compounds.

*Effects on health.* The ozone concentration at ground level causes respiratory system and eye irritation. High ozone concentrations can trigger a reduction of the respiratory function.

*Effects on the environment:* It is responsible for certain damages caused to the vegetation through the atrophy of certain tree species in the urban areas.

*Measurement methods.* The standard methods for the ozone analysis and for the calibration of the ozone-related tools are:

- analysis method: UV photometric method (ISO 13964);
- calibration method: UV reference photometer (ISO 13964, VDI 2468, B1.6).

- **Nitrogen oxides**

*General features.* Nitrogen oxides represent a group of very reactive gases, containing nitrogen and oxygen in variable quantities. Most of these gases have no color and no smell.

The main nitrogen oxides are:

- nitrogen monoxide (NO), a colorless and odorless gas;
- nitrogen dioxide (NO<sub>2</sub>), a brown-reddish gas, with a strong, choking smell.

Combined with the air particles, nitrogen dioxide can form a brown-reddish layer. In the presence of solar light, nitrogen oxides can react as well with hydrocarbons forming photochemical oxidants. Nitrogen oxides are responsible for acid rains, which affect the terrestrial surface and the aquatic ecosystem.

*Anthropic sources:* they appear in the combustion process, when fuels are burnt at high temperatures, but most often they are the result of road traffic, industrial activities, and electric energy production. Nitrogen oxides are responsible for: smog and acid rains formation, water quality deterioration, greenhouse effect, and reduced visibility in the urban areas.

*Effects on people's health.* Nitrogen dioxide is known as a very toxic gas both for people and for animals (its degree of toxicity is four times higher than that of the nitrogen monoxide). Being exposed to high concentrations can be fatal, while low concentrations affect the pulmonary tissue. The population exposed to this type of pollutants can experience respiratory difficulties, respiratory irritations, and pulmonary dysfunction. A durable exposure to a low concentration can destroy the pulmonary tissues, leading to pulmonary emphysema. The most affected people through the exposure to this pollutant are children.

*Effects on plants and animals.* The exposure to this pollutant produces serious damage to the vegetation, by whitening or destroying the plants' tissues, and reducing their growth rhythm. The exposure to nitrogen oxides can cause pulmonary diseases with animals (resembling pulmonary emphysema), while the exposure to nitrogen dioxide can reduce the animals' immunity, causing diseases such as pneumonia and flu.

*Other effects.* Nitrogen oxides contribute to the formation of acid rains and favor nitrate storage into the soil, which can alter the ecological balance of the environment. At the same time, they can cause tissue deterioration, paints discoloring and metal degradation.

*Measurement methods:* the standard method for nitrogen dioxide and nitrogen oxides analysis is mentioned in ISO 7996/1985 - "Aer înconjurător - determinarea concentrației masive de oxizi de azot" ("Surrounding air - the determination of massive nitrogen oxides concentration"), being chemiluminescence.

- **Lead and other toxic metals: Pb, Cd, As and Hg**

*General features.* Toxic metals come from coal, fuel, domestic waste combustion etc. and from certain industrial procedures. They are generally found as particles (except for mercury which is gaseous). Metals are stored in the body and trigger short and/or long term toxic effects. In case of exposure to high concentrations they can affect the nervous system, and the renal, hepatic and respiratory functions.



*Measurement methods:*

- the standard method for lead sampling is the same as the sampling method for PM<sub>10</sub>;
- the standard method for lead analysis is the one mentioned in ISO 9855/1993 “Aer înconjurător - determinarea conținutului de plumb din aerosolii colectați pe filter” (“Surrounding air - determination of particulate lead content from aerosols collected on filter”);
- method - atomic absorption spectroscopy.
- the standard method for measuring the concentrations of arsenic, cadmium and nickel in the surrounding air is about to be standardized by the European Committee for Standardization (CEN) and relies on manual sampling of the PM<sub>10</sub> fraction (described by the EN 12341 standard).

• **Heavy metals**

In Dâmbovița County, including the area of Târgoviște municipality and its surroundings, heavy metal emissions come from: combustion of gaseous fuels, road traffic (to a large extent) (a special role going to the use of fuels with lead derivatives as additives), metallurgical industry activities, building materials industry, and burning of dangerous (hospital) wastes (to a lesser extent).

The determinations for lead, arsenic, cadmium and nickel were carried out starting from breathable dusts - PM<sub>10</sub> fraction -, and for chromium from total dusts in suspension. They were carried out using the automated DB1 and DB2 stations and the manual sampling station situated on the industrial platform in the southwest of Târgoviște municipality; for chromium, other determinations were also carried out in the locality of Doicești (Table 1 and Fig. 3-6).

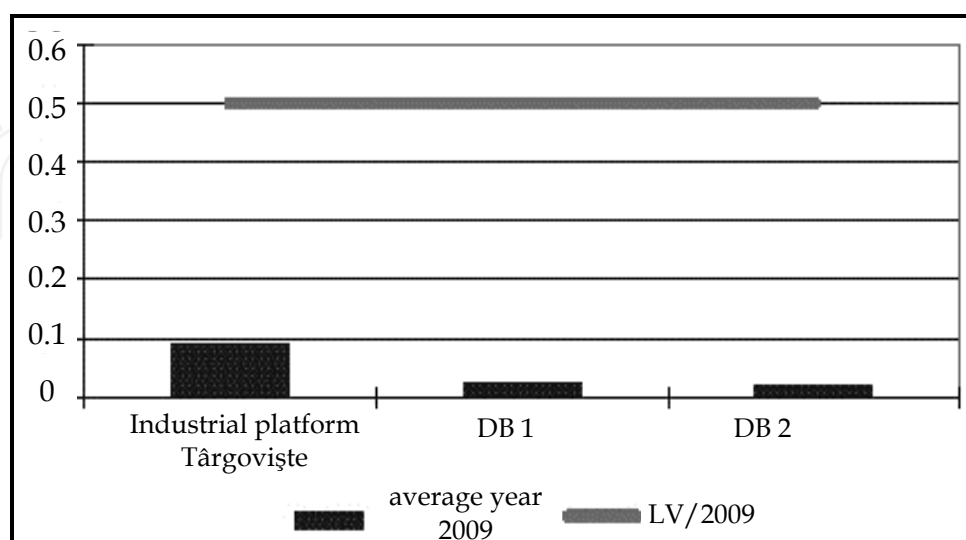


Fig. 3. Average annual concentrations: lead in the year 2009 ( $\mu\text{g}/\text{m}^3$ ).

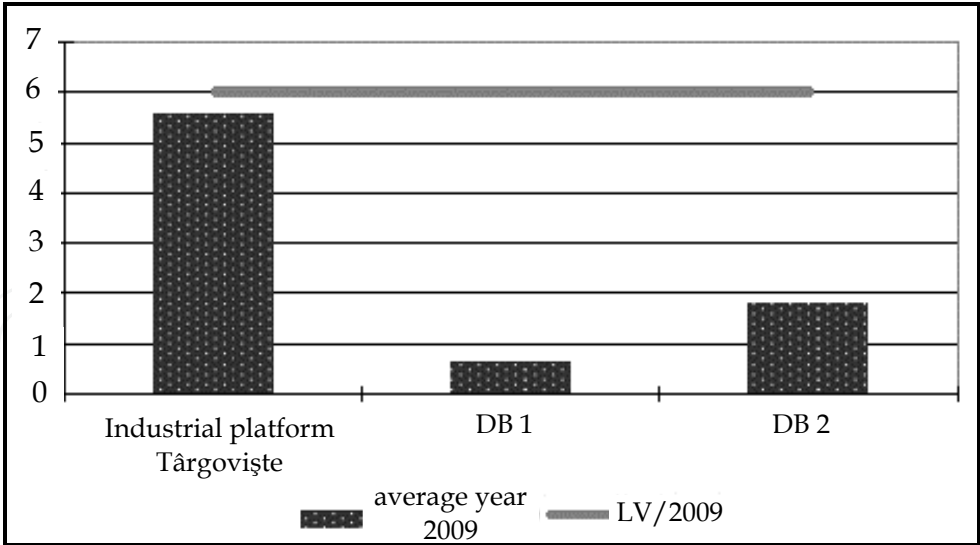


Fig. 4. Average annual concentrations: arsenic in the year 2009 (ng/m³).

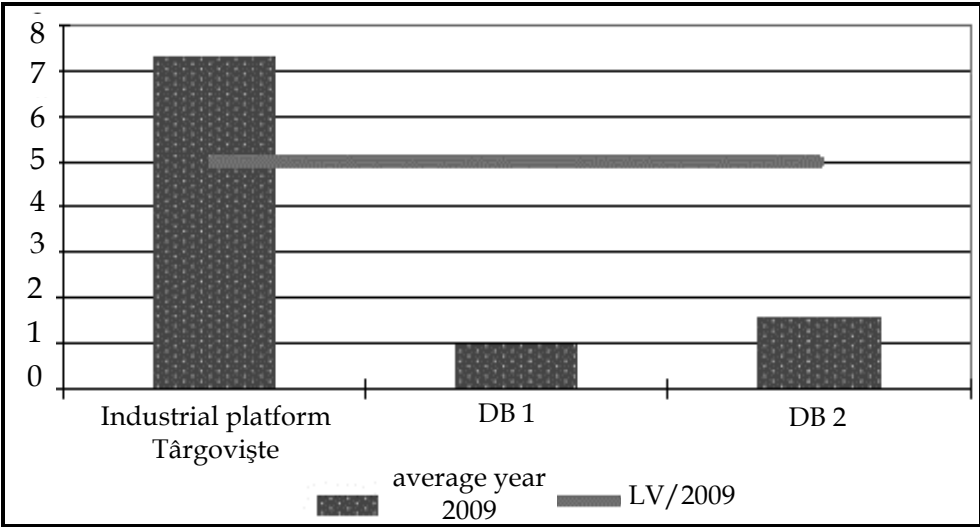


Fig. 5. Average annual concentrations: cadmium in the year 2009 (ng/m³).

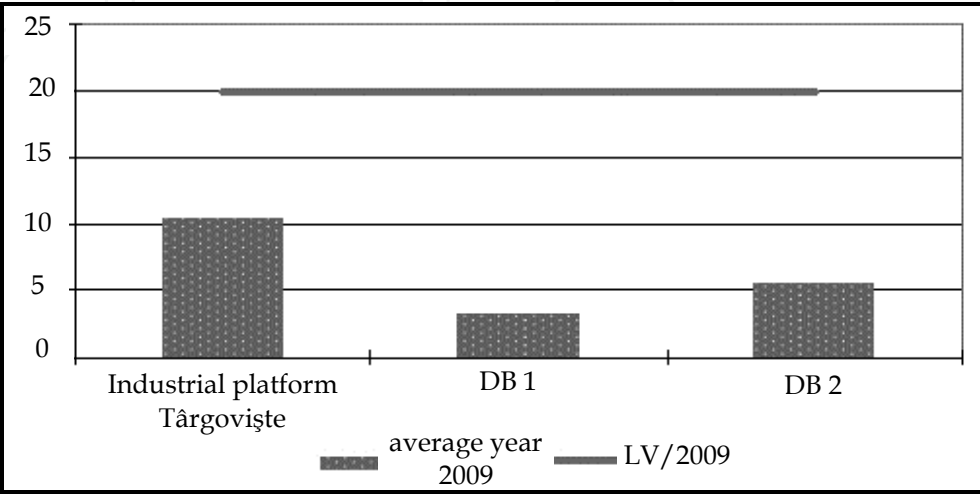


Fig. 6. Average annual concentrations: nickel in the year 2009 (ng/m³).

Station	No. of valid data	Data collecting (%)	Average	Maximum	Median
LEAD (µg/m³)					
DB1	285	78.08	0.0246	0.1623	0.0115
Industrial platform	105	28.77	0.0916	0.5712	0.0628
DB2	307	84.11	0.0205	0.0867	0.0140
ARSENIC (ng/m³)					
DB1	232	63.56	0.6237	15.9719	0.0888
Industrial platform	89	24.38	5.5645	49.9795	1.7821
DB2	251	68.77	1.7854	34.0692	0.0972
CADMIUM (ng/m³)					
DB1	232	63.56	0.9870	10.2118	0.1801
Industrial platform	89	24.38	7.2788	83.9098	1.7728
DB2	251	68.77	1.5757	9.7392	0.9380
NICKEL (ng/m³)					
DB1	232	6356	3.2938	29.5864	0.2516
Industrial platform	89	24.38	10.5071	119.8768	0.0000
DB2	235	64.38	5.4799	51.4799	2.2764
CHROMIUM (mg/m³)					
Doiceşti	193	52.88	0.000033	0.000091	0.000029

Table 1. Values for heavy metals in the year 2009 (source: AEP Dâmbovița).

One can notice an overpassing of the yearly limit value for the protection of human health at the manual station situated on the industrial platform of Târgoviște municipality, for the indicator cadmium, under the reserve that in the year 2009 the data collecting was of 24.4% (89 measurements). The other indicators monitored did not go over the annual limit value (lead, arsenic, zinc) or the maximum admitted daily concentration (chromium). The main polluting units are: SC Cromsteel SA and SC Mechel SA from Târgoviște municipality.

• The tropospheric ozone and other photochemical oxidants

The inventory, according to the order 524/2000, of the sources and of the emissions highlights the following pollutants accumulation concerning the category of volatile organic compounds (VOCs) emitted in the atmosphere during the years 2007-2009 (Table 2):

Year	Total emissions in Dâmbovița County (t/year)		
	Total VOCs	NMVOCs (non-methane volatile organic compounds)	CH <sub>4</sub> (methane)
2007	89127.67	14919.671	74208
2008	19177.99	8451.86	10726.13
2009	15739.2	4075.69	11663.48

Table 2. Tropospheric ozone emissions and other photochemical oxidants (source: AEP Dâmbovița).

So, at present, one can notice a decrease of the non-methane volatile organic compounds, more precisely by 72.7% in 2009 compared to 2007, while concerning methane, a quite significant increase of the quantities emitted during the same periods was recorded, especially because of the increase of the number of cars and of the road traffic intensification, especially in the urban area (Murărescu & Pehoiu, 2009; Pehoiu, 2006).

3.2 Stationary air quality monitoring points

• Pollution with dusts in suspension

As we have mentioned before, in the area of Târgoviște municipality there are:

- the sampling point from Micro XII - point 1 (Constructorului Str., no. 21). Sampling time: 24 h. Indicator – dusts in suspension: fraction PM<sub>10</sub>, Unit of measurement: µg/m<sup>3</sup>; MAC - maximum allowable concentration (50 µg/m<sup>3</sup>);
- the sampling point from Micro XII - point 2 (High School no. 5). Sampling time: 24 h. Indicator - total dusts in suspension (TSP), Unit of measurement: mg/m<sup>3</sup>; maximum allowable concentration - MAC (0.15 mg/m<sup>3</sup>); AT - alert threshold (70% of the MAC = 0.105mg/m<sup>3</sup>) - Table 3.

Maximum value	0.058
Minimum value	0.026
Average value	0.049
Number of determinations	4
No. of situations in which the maximum allowable concentration (MAC) was exceeded	0
% MAC excess	0

Table 3. Concentrations for dusts in suspension: Târgoviște, Micro XII (source: AEP Dâmbovița.

One can notice that in point of the concentrations of dusts in suspension, at least on the level of the quarter Micro XII of the municipality, no overpassing of the MAC was determined.

- sampling point: AEP Dâmbovița headquarters (Ialomiței Str., no. 1); sampling time: 24 h. Indicators – total dusts in suspension (TSP), nitrogen dioxide (NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), ammonia (NH<sub>3</sub>), formaldehyde (CH<sub>2</sub>O); MAC - maximum allowable concentration (0.15 mg/m<sup>3</sup>); AT - alert threshold (70% of the MAC = 0.105mg/m<sup>3</sup>) - Table 4.

Just as in the case of the pollution with dusts in suspension, following the four determinations carried out, it was possible to notice that there was no MAC overpassing for dusts in suspension, the values of the alert threshold overpassing being practically insignificant.



	TSP	NO <sub>2</sub>	SO <sub>2</sub>	NH <sub>3</sub>	CH <sub>2</sub> O
Measurement units	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>
Maximum value	0.054	0.0085	0.0016	0.0049	0.0020
Minimum value	0.026	0.0070	0.0009	0.0036	0.0007
Average value	0.040	0.0076	0.0014	0.0041	0.0011
No. of determinations	4	4	4	4	4
MAC	0.15	0.1	0.25	0.1	0.012
No. of MAC overpassing	0	0	0	0	0
% MAC overpassing	0	0	0	0	0
AT	0.105	0.07	0.175	0.07	0.0084
No. of AT overpassing	0	0	0	0	0
% AT overpasing	0	0	0	0	0

Table 4. Concentrations of dusts in suspension AEP Dâmbovița (source: AEP Dâmbovița).

- sampling point: Micro VI (Unirii Blvd., no. 6)

Sampling time: 24 h. Indicators - nitrogen dioxide (NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), ammonia (NH<sub>3</sub>); MAC - maximum allowable concentration, AT - alert threshold (Table 5).

	NO <sub>2</sub>	SO <sub>2</sub>	NH <sub>3</sub>
Measurement units	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>
Maximum value	0.0124	0.0025	0.0062
Minimum value	0.0090	0.0018	0.0029
Average value	0.0108	0.0021	0.0048
No. of determinations	4	4	4
MAC	0.1	0.25	0.1
No. of MAC overpassing	0	0	0
% MAC overpassing	0	0	0
AT	0.07	0.175	0.07
No. of AT overpassing	0	0	0
% AT overpasing	0	0	0

Table 5. Concentrations presented by AEP Dâmbovița.

The four determinations realized in the sampling point quarter Micro VI of Târgoviște municipality highlight the overpassing of the maximum allowable concentrations for all the pollutants, accompanied by the overpassing of the alert threshold, yet in very low percentages.

AEP monitored the level of the dusts in suspension, in the area of Târgoviște, by means of its three sampling stations: AEP Târgoviște (representative for road traffic), Micro XII (representative for dusts resulted from SC Mechel Târgoviște), Civic Center (representative for dusts resulted from road traffic and other sources after dispersion (SC Mechel SA, SC UPET SA)).

Following four determinations, we noticed that the values of the average concentrations in 24 hours went over the MAC (0.15 mg/m<sup>3</sup>) in all the three sampling points. The frequency of the average overpassing in 24 h for the area of Târgoviște is of 13.94%, the maximum overpassing being of 0.267 mg/m<sup>3</sup> (in the point AEP headquarters) compared to 0.15 mg/m<sup>3</sup> (MAC).

The values of the average yearly concentrations were above the annual MAC (0.075 mg/m<sup>3</sup>) in all the three sampling points and globally in the area of Târgoviște (0.116 mg/m<sup>3</sup>). The main reasons are the dust emissions containing iron oxides and ferrous metals (SC Mechel SA), but also the intense road traffic.

In order to observe the air quality status and the pollution in the north of Târgoviște municipality, the sampling points from the industrial area of Doicești were taken into account as well, having as sampling point the locality's train station, also because the wind direction determines the transport of the dusts from this location to the municipality, along the valley of Ialomița River. Sampling time: 24 h. Indicators - nitrogen dioxide (NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), sulphuretted hydrogen (H<sub>2</sub>S), Cr<sup>6+</sup>, total dusts in suspension (TSP); MAC - maximum allowable concentration; AT - alert threshold (70% of the MAC = 0.105 mg/m<sup>3</sup>) - Table 6 and Fig. 7.

	TSP	NO <sub>2</sub>	SO <sub>2</sub>	H <sub>2</sub> S	CrO <sub>3</sub>
Measurement units	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>	mg/m <sup>3</sup>
Maximum value	0.057	0.0204	0.0033	0.0045	0.0001000
Minimum value	0.029	0.0087	0.0013	0.0017	0.0000840
Average value	0.037	0.0132	0.0020	0.0028	0.0000893
No. of determinations	4	4	4	4	4
MAC	0.15	0.1	0.25	0.008	0.0015
No. of MAC overpassing	0	0	0	0	0
% MAC overpassing	0	0	0	0	0
AT	0.105	0.07	0.175	0.0056	0.0010
No. of AT overpassing	0	0	0	0	0

Table 6. Concentrations reported in the point Doicești Trains Station (source: AEP Dâmbovița).

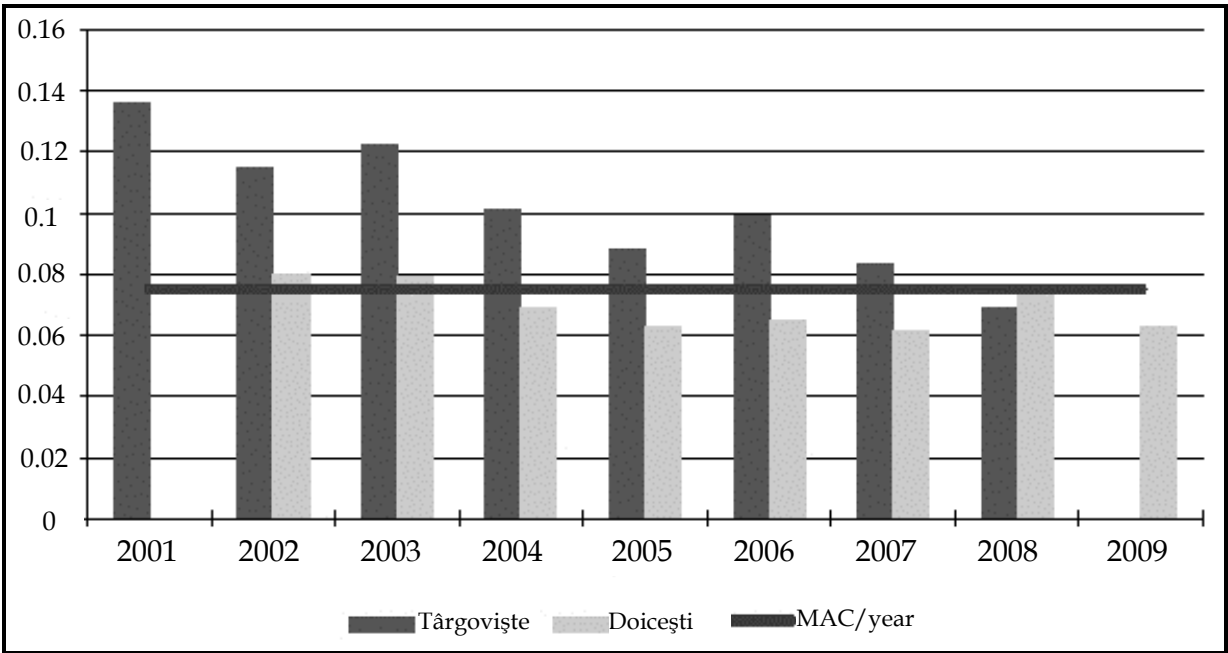


Fig. 7. Evolution of the concentrations of total dusts in suspension during the years 2001-2009 (TSP) - mg/m³

In Doicești locality, one monitored the level of the pollution with settleable dusts, nitrogen dioxide, sulphur dioxide, sulphuretted hydrogen, dusts in suspension, given the specific emissions from the main polluting economic agents in the area: U.E. Doicești, which uses black oil and brown coal as fuel to generate electricity and SC Nubiola România SRL (a company producing whiteners and green chrome oxide) - the SO<sub>2</sub> and possibly a sulfuretted hydrogen source in the process of sulphur combustion needed to obtain ultramarine.

Other potential pollutants are SC. Soceram SA (producer of bricks, ceramic materials) and road traffic. The evolution of the concentrations of total dusts in suspension, during the period 2001 - 2009, clearly highlights the diminution in the atmosphere of these polluting emissions, both for the municipality and for Doicești locality.

• **Pollution with settleable dusts**

AEP supervises the level of the settleable dusts in the areas of Târgoviște and Doicești. Under exceptional conditions of air masses transportation along Ialomița River, settleable dusts from the industrial area of Fieni can end up in Târgoviște and its surroundings. That is why we consider it necessary to include Fieni locality as well in the present study. In these areas, a characteristic feature is the pollution with dusts, the main polluting sources being:

- in Târgoviște: SC Mechel SA, SC Upet SA and to a lesser extent the road traffic; the major impact is felt under the form of dusts in suspension;
- in Doicești: UE Doicești, SC Soceram SA, road traffic; given the emissions' features, the major impact is felt under the form of settleable dusts. Dusts in suspension have been monitored in the area starting with June 2002.
- in Fieni: SC Carpatcement Holding SA (producer of lime and cement); the major impact is felt at the same time under the form of settleable dusts. Dusts in suspension have been monitored in the area starting with March 2003.

Concerning each locality, the average annual quantities of settleable dusts did not go over the annual MAC (204 t/km<sup>2</sup>/year) in none of them, yet in different sampling points the annual average values have been exceeded, namely in the points situated in inhabited areas in which the impact of the dusts emissions from the sources is high (Fig. 8).

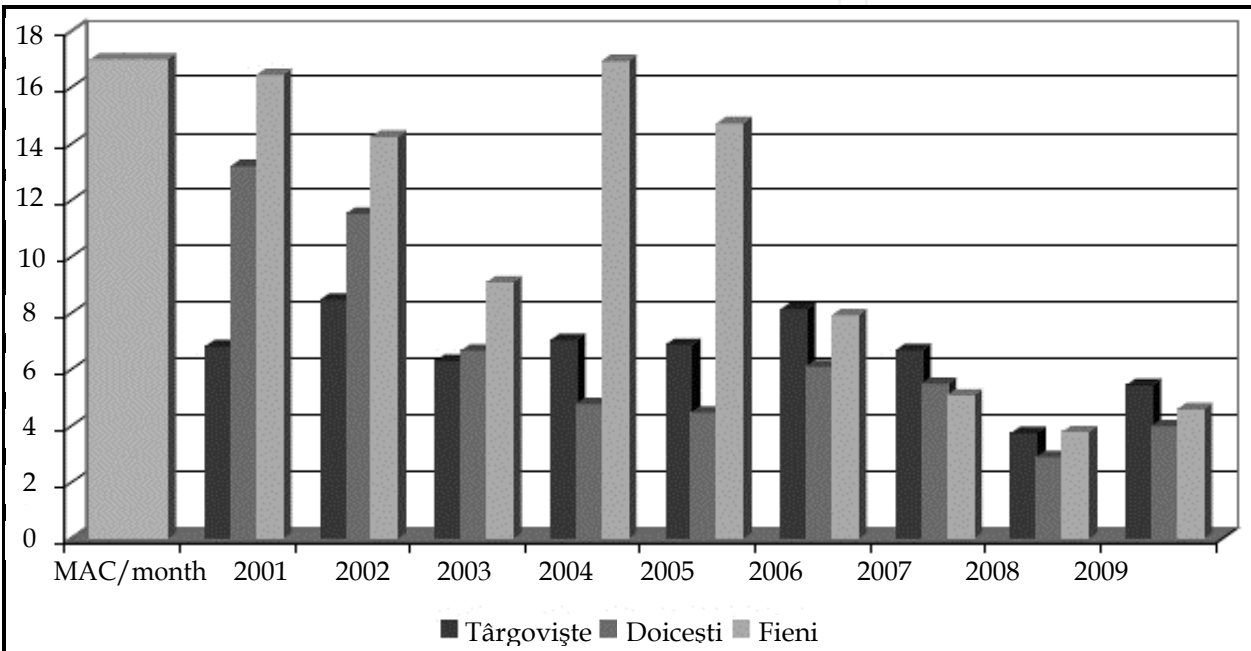


Fig. 8. Evolution of the concentrations of settleable dusts during the years 2001-2009 (mg/m<sup>3</sup>).

3.3 Experimental results and syntheses concerning the automatic monitoring of the emissions of atmospheric pollutants

• Târgoviște area

For the indicator dusts in suspension - the PM<sub>10</sub> fraction - (Procor headquarters, industrial platform), on 13 occasions one recorded values above the limit value (50 µg/m<sup>3</sup>) in 24 hours (out of the 15 measurements carried out). In the year 2009, the level of dusts in suspension was analyzed in the localities Târgoviște (PM<sub>10</sub> - manual station located on the industrial platform and industrial automatic station - DB1), Doicești (total dusts in suspension (TSP) - manual station) and Fieni (industrial automatic station - DB2) - Table 7 and Fig. 9-13.



Station	No. of valid data	Data collecting (%)	No. of data >LV	Frequency of the overpassing (%)	Average (µg/m³)	Maximum (µg/m³)	Median (µg/m³)	Percentile 98 (µg/m³)
TÂRGOVIȘTE								
DB1, automatic	272	74.52	6	2.21	19.665	55.373	15.634	48.942
DB1, gravimetric	286	78.36	1	0.35	19.594	50.150	19.079	43.848
Industrial platform, gravimetric	142	38.90	87	61.27	57.629	118.387	57.364	106.567
DOICEȘTI								
Train Station	194	53.15	0	0	0.063	0.148	0.059	0.136
FIENI								
DB2, automatic	335	91.78	11	3.28	22.101	89.920	19.425	55.581
DB2, gravimetric	307	84.11	8	2.61	18.739	75.043	15.808	53.060

Table 7. Indicators PM<sub>10</sub> per 24 h in 2009 (source: AEP Dâmbovița).

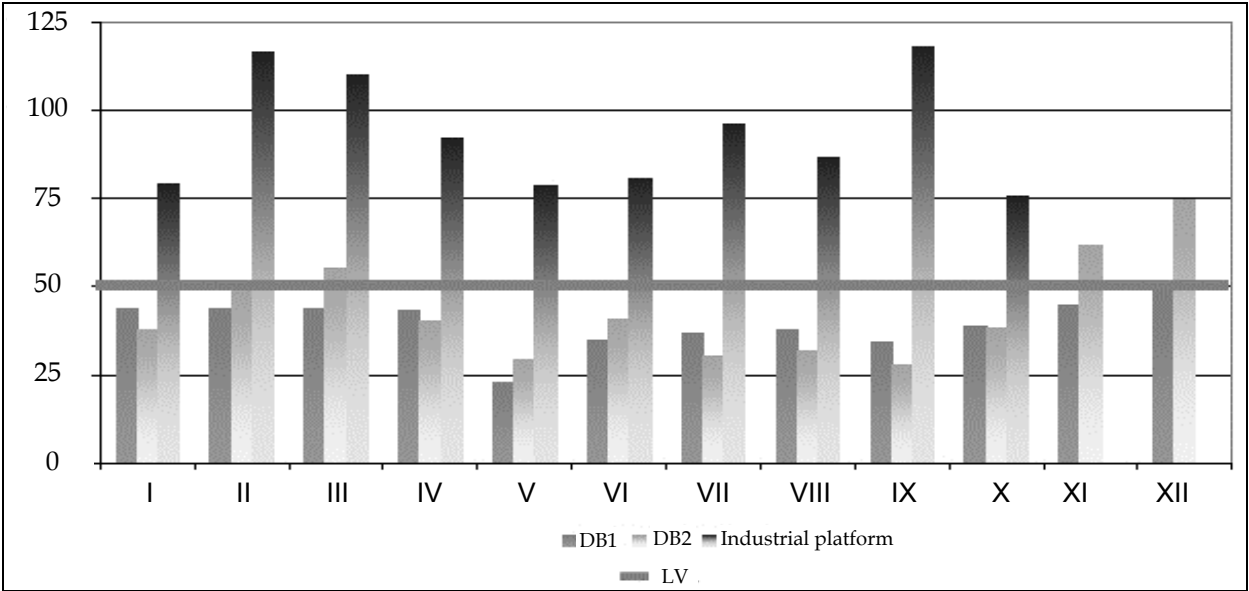


Fig. 9. Maximums/24h of the PM<sub>10</sub> indicator, measured gravimetrically (months) - year 2009, compared to LV/24h (µg/m³).

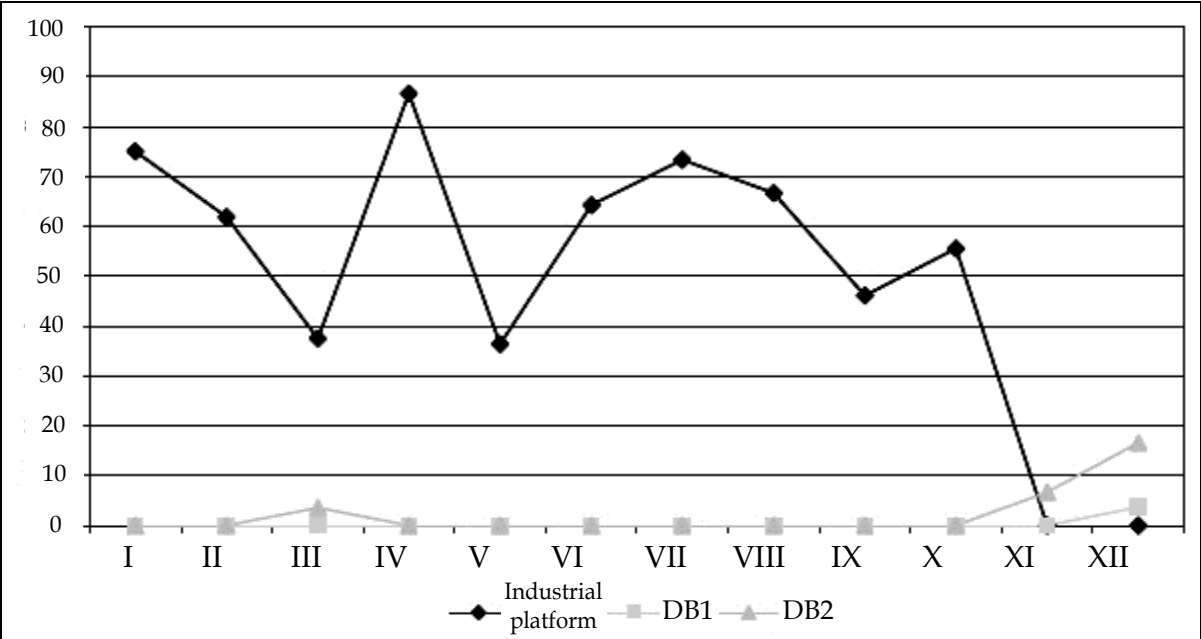


Fig. 10. Monthly frequencies of the exceeding of the LV/24h – dusts in suspension (PM<sub>10</sub>) in the year 2009 (%).

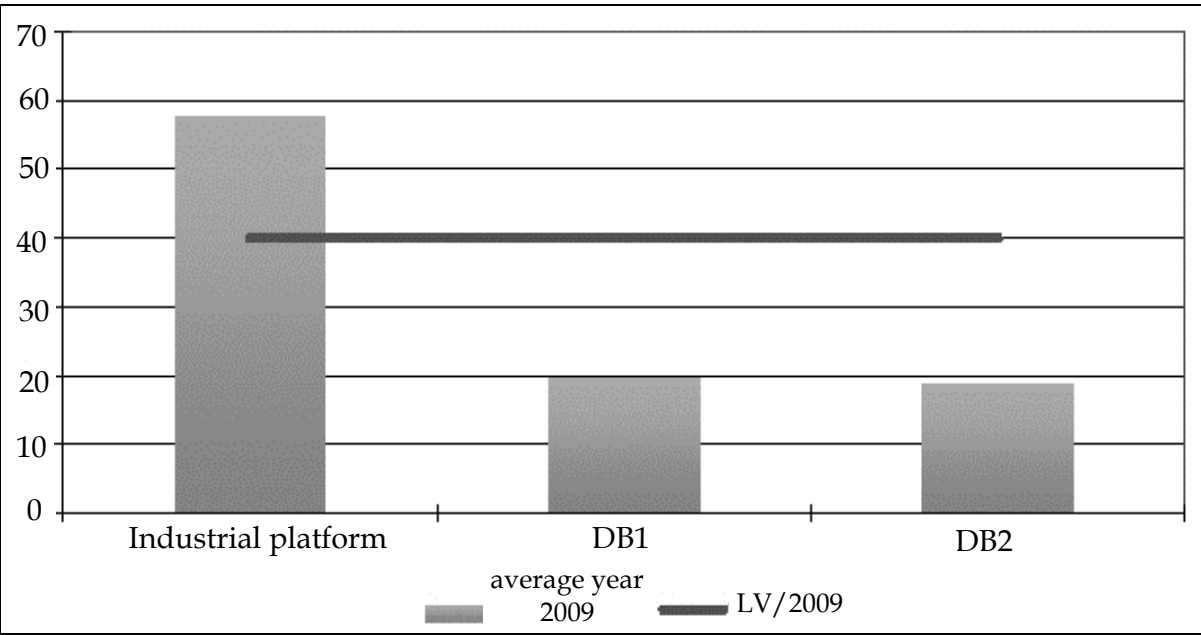


Fig. 11. Average annual concentrations of the PM<sub>10</sub> indicator, measured gravimetrically (µg/m<sup>3</sup>).

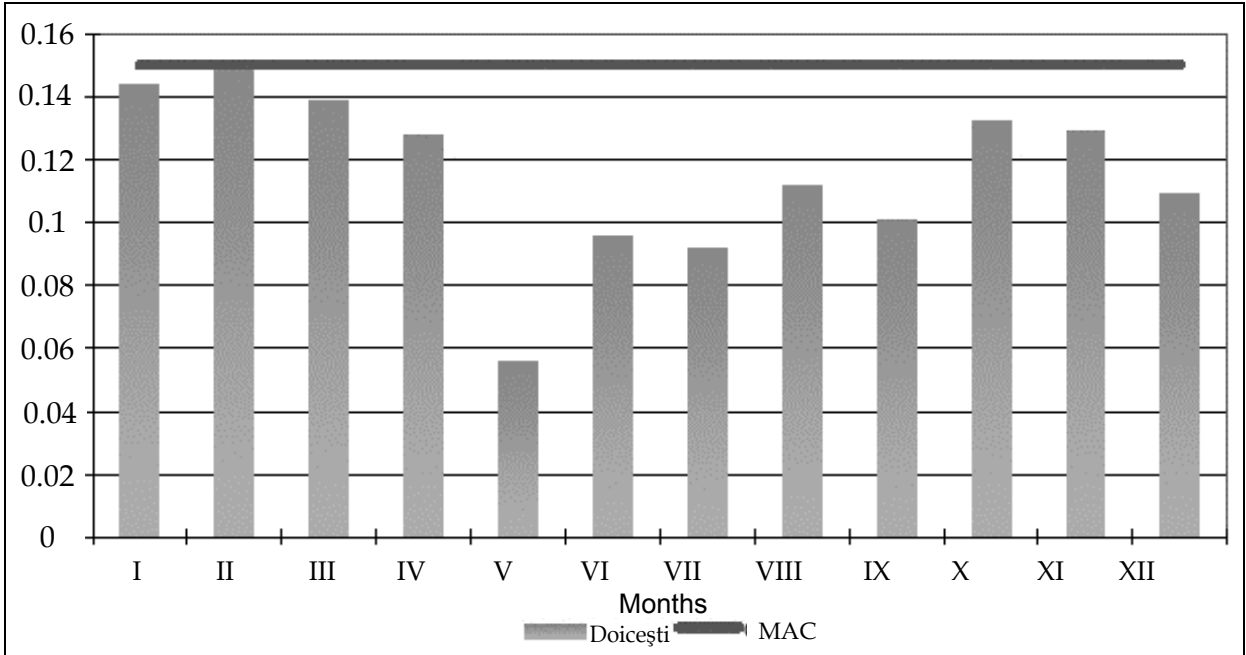


Fig. 12. Maximums/24h of the TSP indicator in Doicești Commune - year 2009 ( $\mu\text{g}/\text{m}^3$ ).

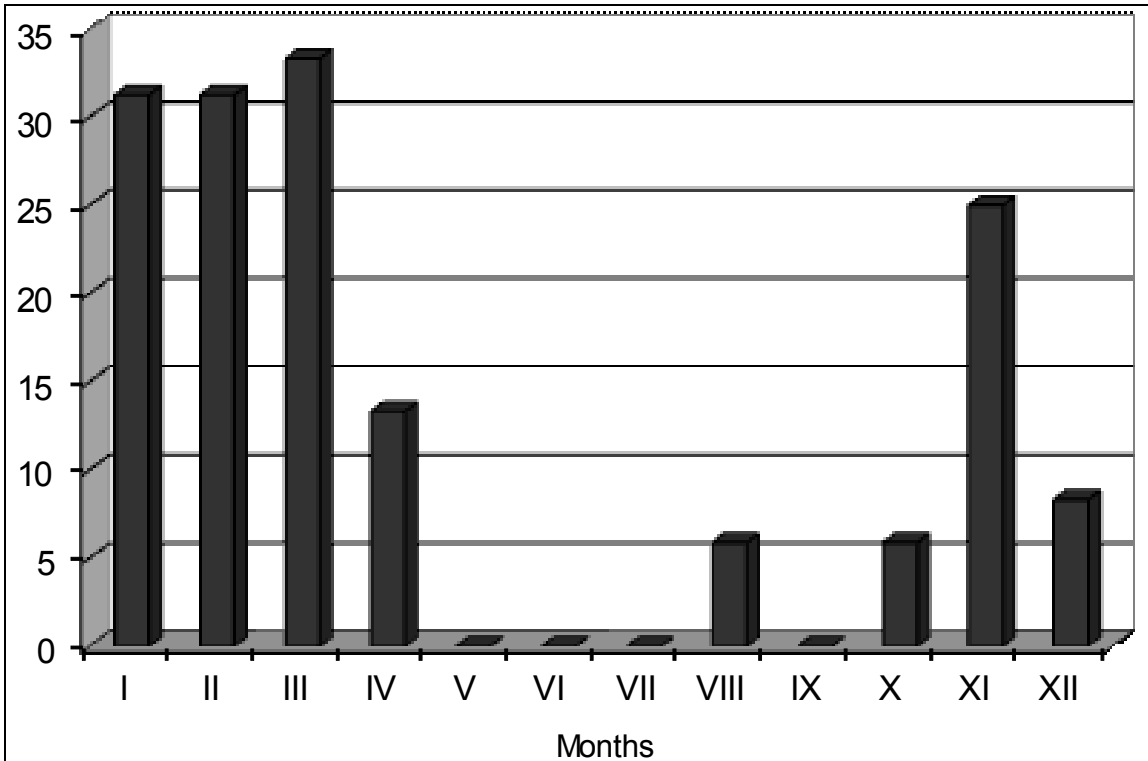


Fig. 13. Monthly frequencies for the exceeding of the AT/24h, Doicești locality, TSP indicator (%), year 2009.

According to the values recorded for the  $\text{PM}_{10}$  indicator, in April 2009, one can notice the increase of the frequency for the exceeding of the limit value to 86.7% (compared to 37.5%, the previous month), the average monthly concentration being of  $68.7 \mu\text{g}/\text{m}^3$ , compared to  $52.6 \mu\text{g}/\text{m}^3$  in March the same year (Table 8).

Maximum value of the concentration ( $\mu\text{g}/\text{m}^3$ )	Minimum value of the concentration ( $\mu\text{g}/\text{m}^3$ )	Average of the values recorded ( $\mu\text{g}/\text{m}^3$ )	Frequency of the overpassing of the LV%
92.2	34.5	68.7	86.7%

Table 8. Average, maximum, minimum monthly quantities for settleable dusts and the frequencies for the exceeding of the monthly MAC (Micro XII, point 1, Târgoviște).

At the Automatic station DB-1, Micro 11, Târgoviște, no exceeding of the limit value for the indicator  $\text{PM}_{10}$  gravimetric, the average monthly value being of  $20.73 \mu\text{g}/\text{m}^3$  (Fig. 14).

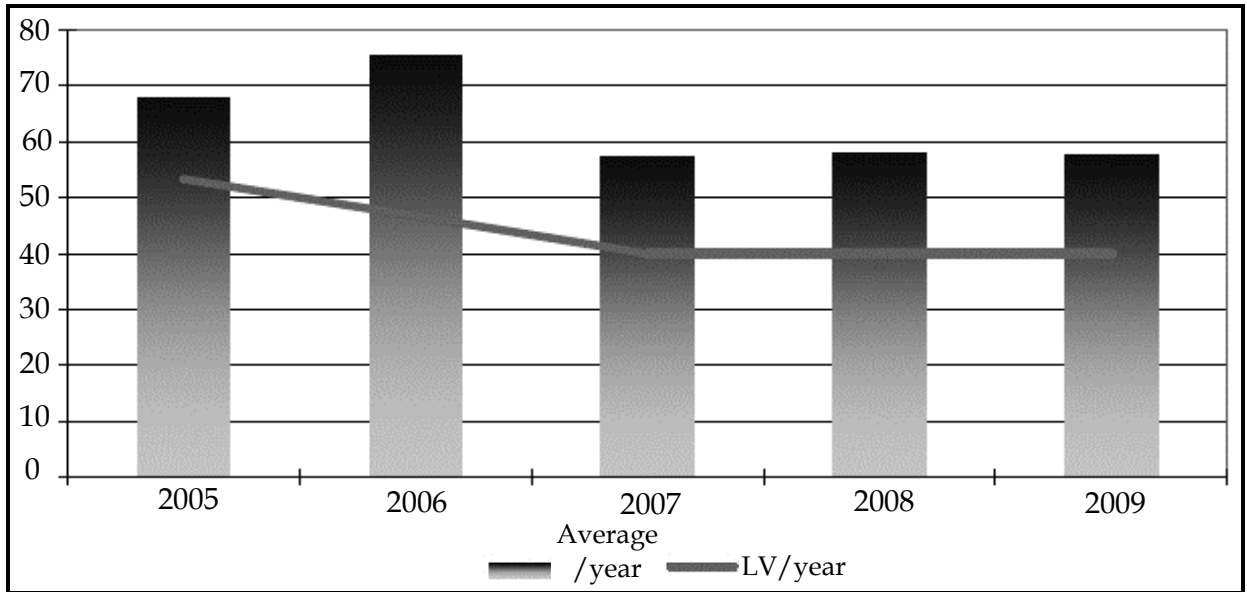


Fig. 14. Evolution of the concentrations of breathable dusts -  $\text{PM}_{10}$  fraction, Târgoviște, Micro XII, manual station ( $\mu\text{g}/\text{m}^3$ ), years 2005-2009.

The dusts concentration in the atmosphere in the sampling area is influenced by the input from nearby sources (activities in the domain of building materials) and of the nearby sources from a distance of about 1 km (activities such as steel production, slag processing etc.). At the same time, the  $\text{PM}_{10}$  concentration can have high values depending on the evolution of the meteorological phenomena: high relative humidity (RH), atmospheric pressure and wind intensity may lead to the appearance of “peaks” of the  $\text{PM}_{10}$  concentrations, because they can favor the agglomeration of the particles.

In Târgoviște municipality, the main sources generating dust emissions (with significant impact in the area around their activity) are the activities of the economic agents from the area of the industrial platform, which operate in the metallurgical domain, in the domain of metallic ware, road transport, building materials, concrete production and road traffic.

In the case of gaseous pollutants, at the Automatic monitoring station DB-1 there was no exceeding of the limit values or the information thresholds for the average hourly or daily concentrations for the indicators monitored. The main sources emitting gaseous pollutants in the area of Târgoviște, with a potential impact on the air quality are: metallurgical



companies, industrial companies that use solvents, economic agents operating in the domain of metallic ware, road transport, building materials, fuel distribution stations and road traffic.

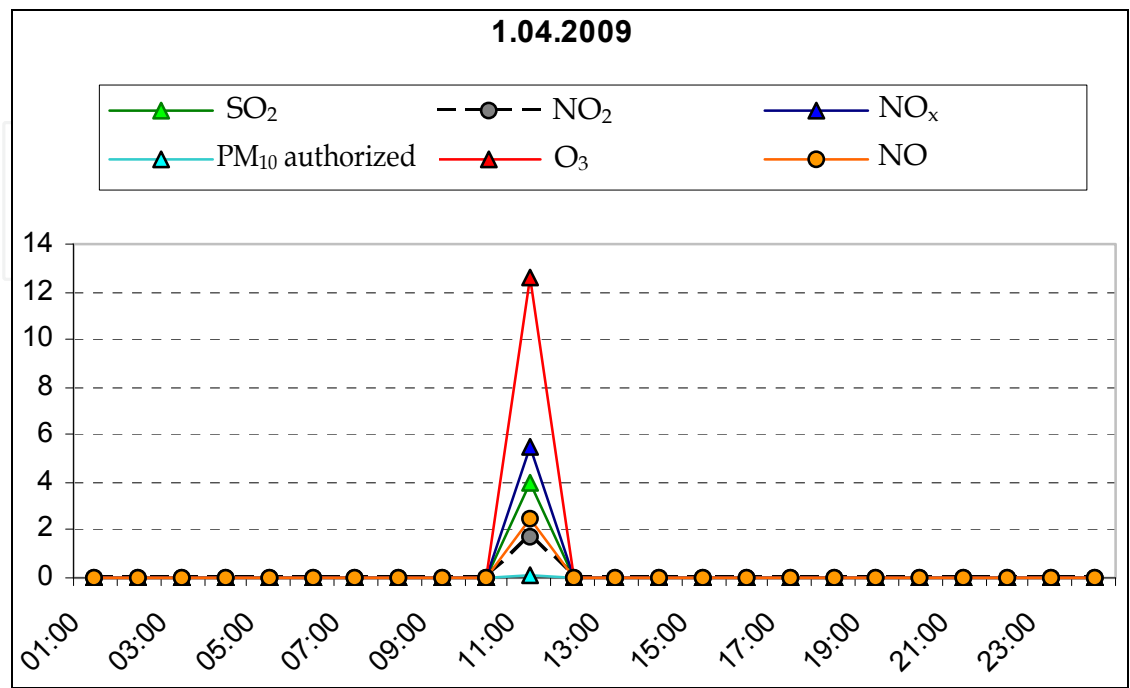
4. Air quality status

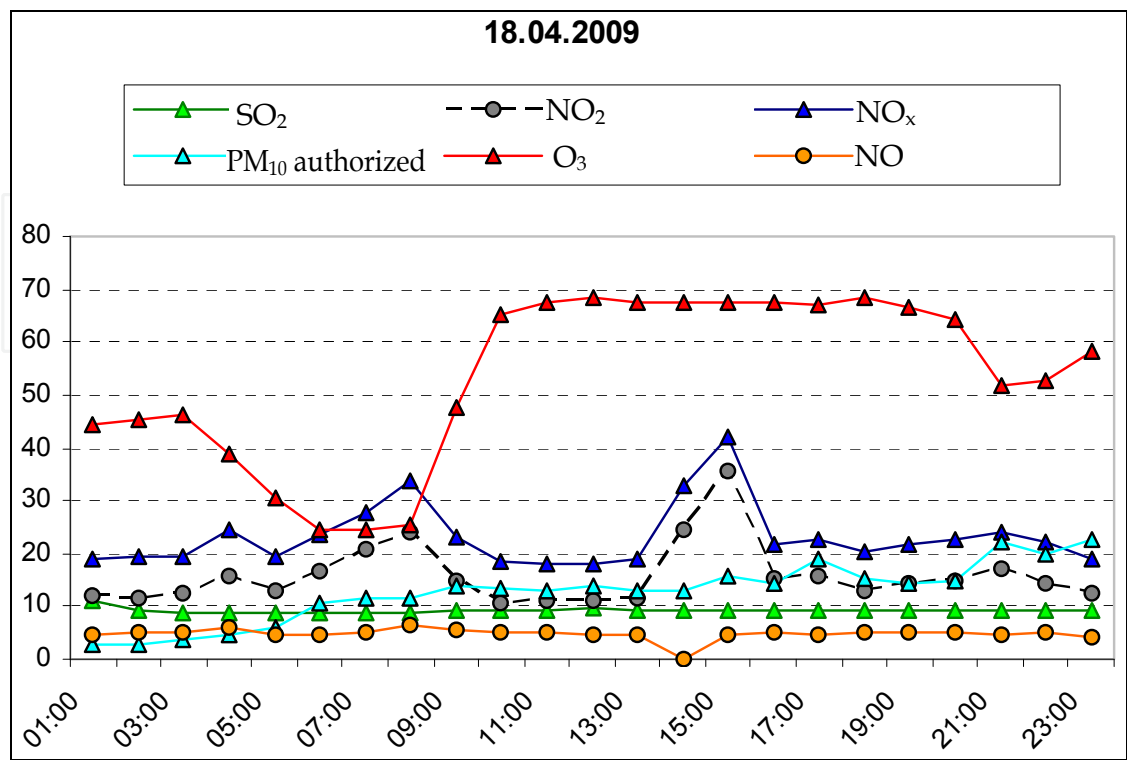
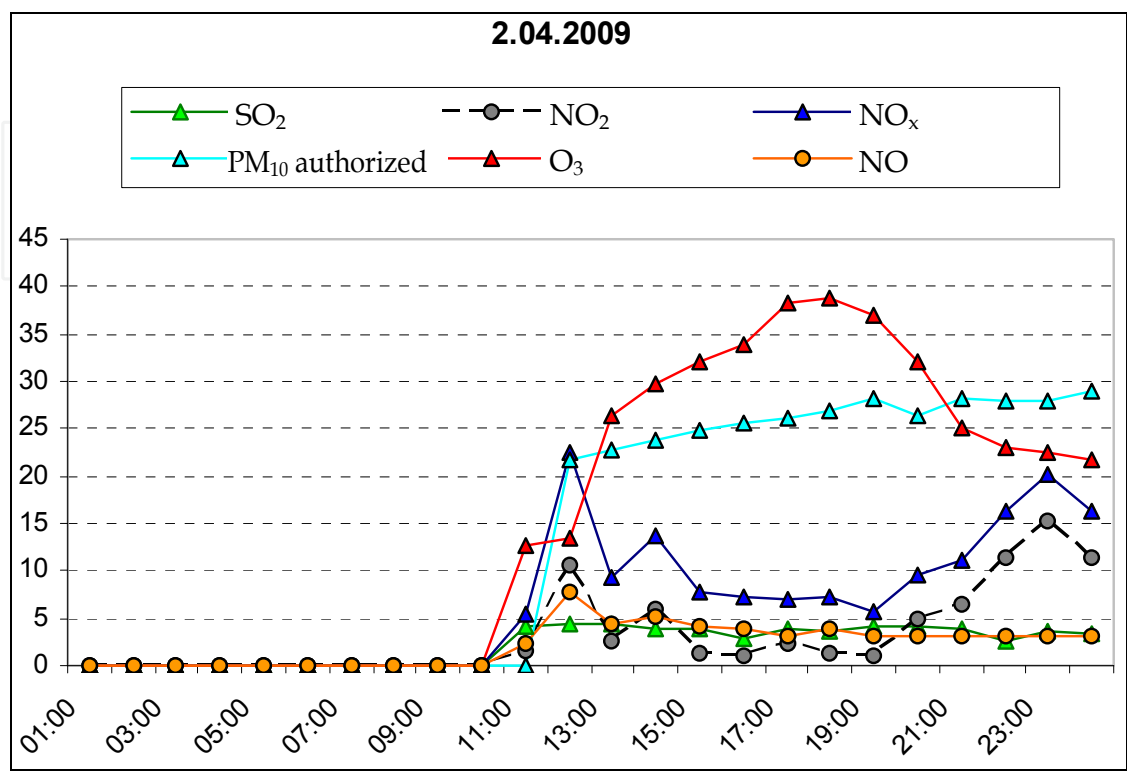
In Târgoviște municipality one monitors daily concentrations (sampling time: 24 h) for the indicators: breathable dusts, respectively the fraction with the diameter <10µm (PM<sub>10</sub>), settleable dusts, highlighting the quantity of (settleable) dusts deposited during a 30-day interval on a 1 m<sup>2</sup> area, this being a characteristic indicator for highlighting the pollution with heavy particles in suspension, which are later on deposited on the ground.

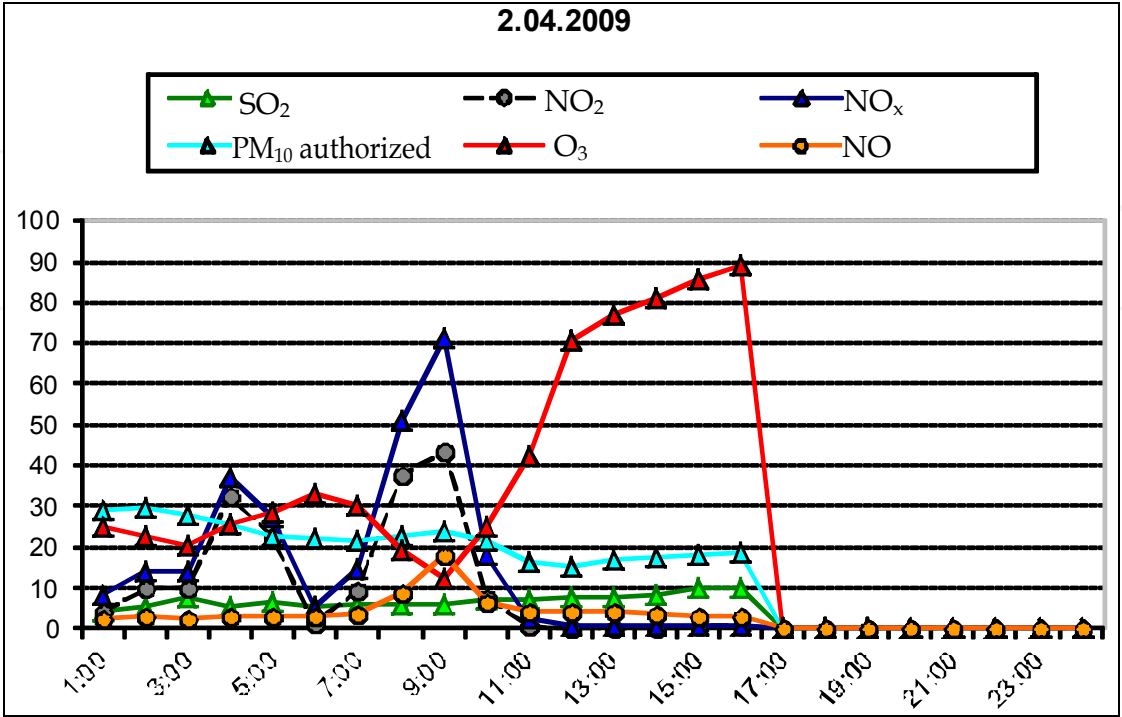
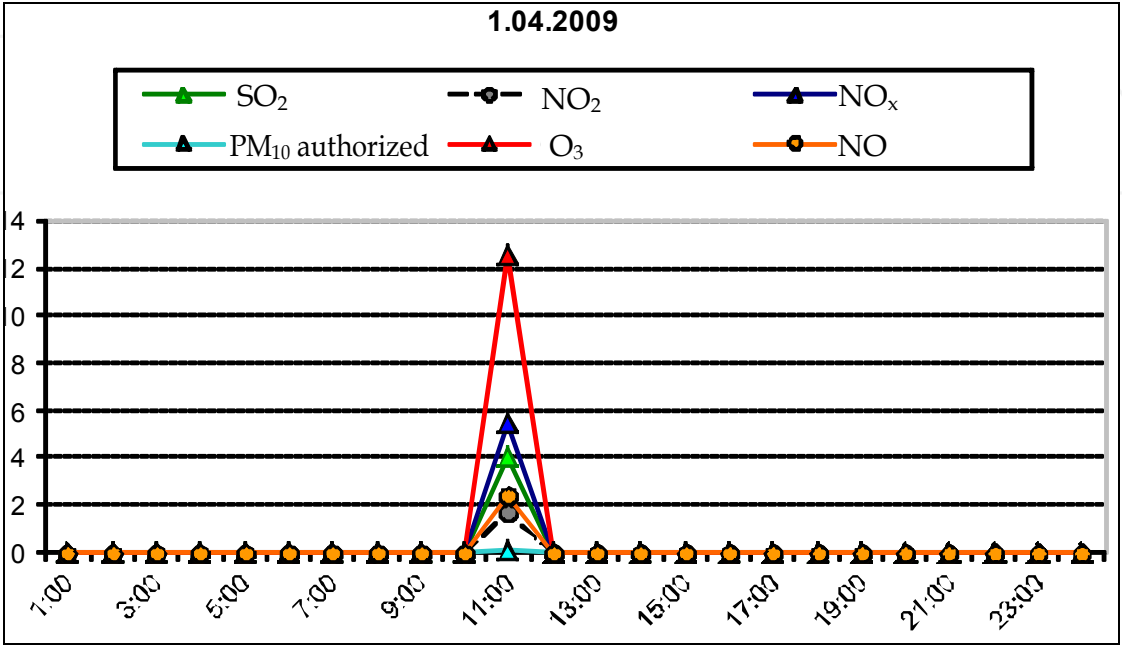
At the same time, the automatic station DB-1 Târgoviște, which continually monitors meteorological parameters (temperature, wind speed, wind direction, solar radiation intensity, precipitations quantity, atmospheric pressure), gaseous pollutants (nitrogen oxides, sulphur dioxide, carbon monoxide, tropospheric ozone) and dusts in suspension (breathable - PM<sub>10</sub> fraction) transmits the data, in real time, to the panels dedicated to public information (external panel - Prefecture Plateau of Târgoviște - and internal panel - AEP Dâmbovița headquarters) - Fig. 15.a-b.

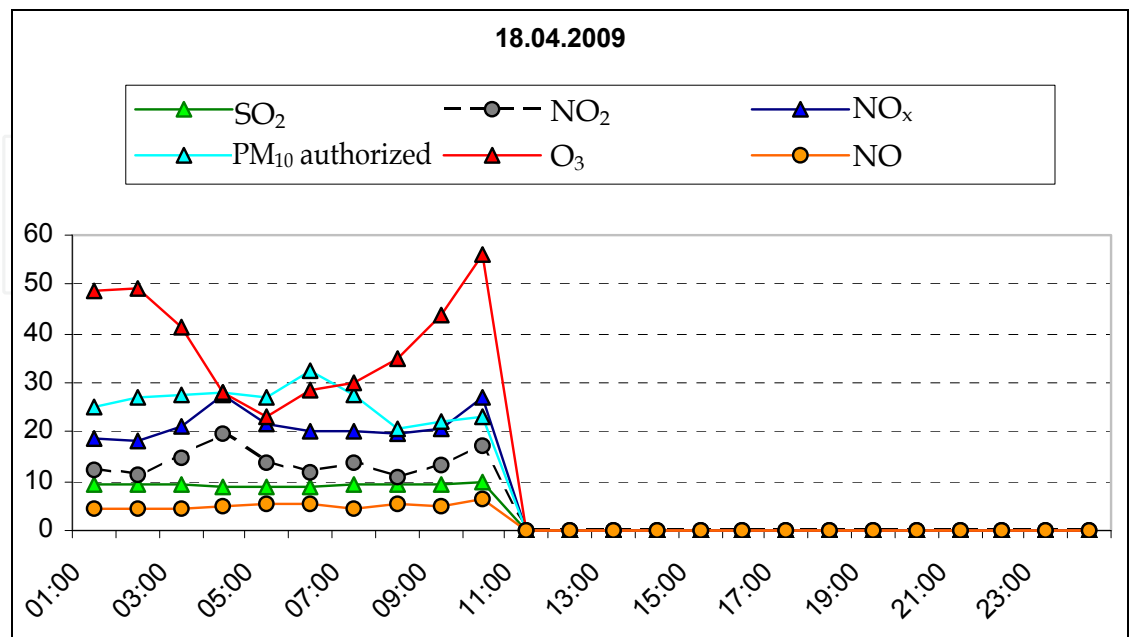
In Doicești locality, air quality is monitored by supervising the indicators total dusts in suspension, settleable dusts and gaseous pollutants (sampling point: manual/urban station).

4.1 Examples of chronological series recorded during a day, (April 1-2 and 18, 2009), at the automatic station DB-1 Târgoviște (concentration in µg/m<sup>3</sup>)









5. Air quality management

5.1 Goals and measures for air quality management

Air pollution represents a serious problem, with short, medium and long term effects. The air, as environmental factor, is submitted to an intense local pollution, especially in the urban area under analysis, because of the industrial activity, because of the intensification of the road traffic and also because of the burning of domestic waste. The air pollution effects can be direct, affecting the local population’s health condition, and also indirect, affecting fauna, flora and building materials.

The goals and measures foreseen on the level of Dâmbovița County and implicitly for all the localities under analysis, in order to improve the air quality in the urban area, in agreement with the quality standards, refer to: reducing the impact of the road traffic on the air quality, reducing the emissions from individual heating systems, assuring the control of the emissions from industrial sources and installing de-pollution equipments for all the sources with a major impact.

There are priorities concerning volatile organic compounds (VOC) emissions control; they aim to limit the emissions coming from the use of organic solvents in certain activities and installations (protective cover, dry cleaning, fabrication of covering compounds and varnishes; surface cleaning and degreasing; wood impregnation) and to meet the legal regulations in this domain.

Considering the fact that industrial pollution represents the main source of pollution for all the environmental factors (affecting the quality of the air, water, soil, generating different types of waste and using natural resources and energy), the purpose of the *integrated*



*environmental protection system* is the implementation of preventive measures or the emissions reduction with the purpose of protecting the environment as a whole.

The industrial branch with the highest impact on the environmental factors is metallurgical industry, the air quality being affected by: emissions resulted from raw matter preparation (iron melting), final products processing, raw matter and auxiliary products transport and storage.

A significant impact on the environmental factors comes from the building materials industry as well (through the existence of the previously mentioned economic agents); their specific activities determine the elimination of large quantities of dusts and green house effect gases in the atmosphere.

On the level of Dâmbovița County, eleven environmental authorizations have been issued concerning the emissions of green house effect gases, for installations under the regulations of the EU-ETS (EU - Emission Trading System) Directive, for the period 2008-2012 (The directive 87/2003/CE was adopted by the Romanian legislation through the governmental decision H.G. no.780/2006)<sup>1</sup>.

The integrated authorizations contain demands and limit values regarding the emissions, which try to make sure that all the adequate preventive measures for the environmental protection have been taken. The limit values concerning emissions are established based on the best available techniques. In order to support the EU member states in the application of the IPPC (International Plant Protection Convention) Directive, among the member states and the afferent industry, there has been an information exchange concerning the BAT - Best Available Techniques. The purpose of this information exchange is to balance differences on a technological level in the European Community and to promote universal limit values and techniques.

In the areas affected by industrial pollution, through adjustment programs annexed to the environmental authorizations emitted for the polluting economic agents, one established measures for the reduction of the industrial activities' impact on the environmental quality. They are found as well in the Local Action Plan for the Environement of Dâmbovița County (Planul Local de Acțiune pentru Mediu al Județului Dâmbovița), reviewed even since the year 2007. Among the local economic agents concerned there are: SC Mechel SA, SC Termica S.A, SC Oțelinox SA, all from Târgoviște, SC Termoelectrica SA București - the branch of Doicești, SC Soceram SA București - the branch of Doicești, SC Carmeuse Holding SRL - working point of Fieni, SC Carpatcement Holding SA - the branch of Fieni.

Following the approval by the National Agency for Environmental Protection (Agenția Națională pentru Protecția Mediului - ANPM) of the Propositions of measure plans for

---

<sup>1</sup>A certificate concerning the green house effect gases emissions represents the title giving an installation the right to emit a ton of carbon dioxide equivalent during a definite period; it is valid for meeting the goal of the governmental decision H.G no. 780/2006 and transferable under the conditions foreseen by this normative act.

green house effect gases emissions monitoring and reporting for the year 2010, the environmental authorizations concerning this type of emissions were reviewed.

The joint implementation (JI), according to the Kyoto Protocol, concerning the advantages of the project for Târgoviște municipality, considered the following aspects:

- producing non-polluting electric and thermal energy using modern, reliable installations, with high energetic efficiency;
- assuring the necessary thermal energy for the municipality of Târgoviște from its own source for the following 20 years;
- realizing 1,959,461 Euro worth investments in the infrastructure without using funds from the state budget;
- creating new jobs;
- encouraging other foreign investments in the municipality.

The ERU 04/04 Contract was concluded between Senter Novem Agency from Holland, from the part of the Government of Holland, and SC Nuon Energy Romania SRL Sibiu, Romania - Project Developer, on September 28, 2004. In the year 2010 a transfer agreement was concluded on the basis of the ERU 04/40 Contract from SC Nuon Energy Romania SRL to SC Termica SA Târgoviște. The emission reductions generated by the project beginning with January 1, 2010 are dealt with by SC Termica SA Târgoviște and the above-mentioned Hollandese agency (Local Plan of Action for Environment of Dâmbovița County, 2010).

## 6. The air quality in relation to the population's health condition

The environment in which people live is first of all defined by the quality of the air, of the water, of the soil, of the dwellings, of the foods they eat, and of the environment in which they deploy their activity. Closely connected to these factors, influenced or determined immediately or after a certain period of time is the population's health condition.

The evaluation of the population's health condition consists in the identification of the hazard factors that in the urban area have an influence on: air quality; potable water supply; gathering and removing liquid and solid residues of any nature; urban noise; habitat – improper conditions (noise, light, population agglomeration etc.); services quality (of all types) provided to the population (Pehoiu et al., 2006).

Knowing and determining some environmental hazard factors is particularly important and may constitute one of the most valuable activities related to the promotion and maintaining of the population's health condition (Pehoiu & Murărescu, 2009).

The action of the environmental factors on human health is very diverse. When the pollution intensity is higher, the action on organisms is immediate. However, more often than not, their action has a low intensity, determining a chronic, long-term action, the quantification of the effect becoming difficult to achieve. The atmospheric pollution in general and especially the exposure to dusts in suspension produces diseases of the respiratory, digestive, osteo-muscular and nervous systems and of the sensory organs, affecting all the age groups; however, when it comes to children, it determines an early predisposition to

respiratory diseases and bronchial asthma. The irritating capacity of the dusts in suspension increases when, in the air, there are other irritating respiratory pollutants, such as SO<sub>2</sub> and NO<sub>2</sub>, as a synergic effect comes into operation from the SO<sub>2</sub> - dusts in suspension and NO<sub>2</sub> - dusts in suspension (Table 9).

Types of diseases	Number of occurrences
1. Diseases of the respiratory system, of which: - acute bronchitis - chronic bronchitis - bronchial asthma	1963 123 110
2. Digestive diseases	8168
3. Cardiovascular diseases	4841
4. Endocrine and metabolic diseases	2966
5. Malignant tumors, of which: - pulmonary cancer	21
6. Congenital malformations	16
7. Renal system diseases	7962
8. Flu	43

Table 9. Specific morbidity on the level of the year 2009 in the urban area of Dâmbovița County (source: Public Health Direction of Dâmbovița County).

In the prevention of diseases caused by the exposure of the population to different atmospheric pollutants, a special importance goes to their prophylaxis. In this sense, one should have in view the maintaining of the concentration of the toxic substances from the environment under the level of the maximum allowable concentrations (MAC) stipulated in the norms (STAS).

7. Conclusions

In Dâmbovița County and implicitly in Târgoviște municipality and its surroundings, the distribution of the sampling equipments available and the organization of the air quality monitoring network was carried out in the sense of assuring especially the monitoring of the areas most likely to be affected by impact pollution.

The pollutants to be monitored, the methods of measurement, the limit values, the alert and the information thresholds and the criteria for the location of the monitoring points are established by the national legislation concerning the atmospheric protection and meet the requirements foreseen by the European regulations.

The air quality has undergone a slight improvement compared to the previous years from the viewpoint of the pollution with different dusts.

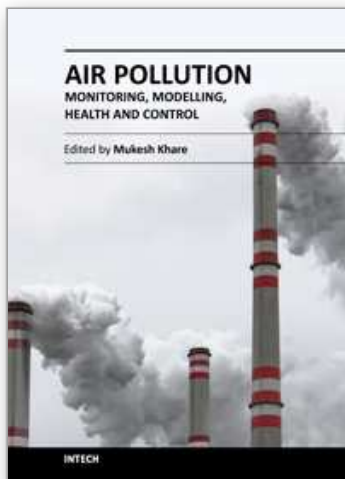
The gaseous pollutants (nitrogen dioxide, sulphur dioxide, ammonia, sulphuretted hydrogen, formaldehyde, oxidant substances, and carbon monoxide) are not present in the atmosphere in concentrations above the allowable limits in the areas in which they are monitored.

The dominant pollution is represented by dusts in suspension (in the area of Târgoviște, in Doicești and its surroundings), and by pollution with settleable dusts in Fieni area.

## 8. References

- Agencia Națională pentru Protecția Mediului (National Agency for Environment Protection), statistical data, 2000-2010, Bucharest, Romania.
- Anuarul statistic al județului Dâmbovița* (Statistical Yearbook of Dâmbovița County), 2000-2010, Târgoviște, Romania.
- Direcția de Sănătate Publică Dâmbovița (Public Health Department Dâmbovița), statistical data, 2000-2010, Târgoviște, Romania.
- Direcția Județeană de Statistică Dâmbovița (Statistical Department of Dâmbovița County), statistical data, 2000-2010, Târgoviște, Romania.
- Ministerul Mediului și Pădurilor (Ministry of Environment and Forestry), statistical data, 2000-2010, Târgoviște, Romania.
- Murărescu, O.; Pehoiu, G. (2009). Integrated management of environmental pollution due to the County Dâmbovița industrial activity. *Annals - Food Science and Technology*, Vol. 10, Issue 2, 2009, pp. 681-686, ISSN 2065-2828, "Valahia" University, Târgoviște, Romania.
- Pehoiu, G. (2003). *Câmpia Înaltă a Târgoviștei. Studiu de geografie umană și economică* (Târgoviște High Plain. Study of Human and Economical Geography), Cetatea de Scaun, ISBN 973-7925-01-7, Târgoviște, Romania.
- Pehoiu, G. (2006). Actual aspects related to the quality of the air in the county Dâmbovița, in report with the status of health of the population. International Multidisciplinary Symposium „Universitair Sempro 2006”, *Ingineria mediului* (Environment Engineering), ISSN: 1842-4449, Petroșani, 2006.
- Pehoiu, G.; Muică, C.; Sencovici, M. (2006). *Geografia mediului cu elemente de ecologie* (Environment Geography with Elements of Ecology), Transversal, ISBN (10) 973-7798-32-5, ISBN: (13) 978-973-7798-32-9, Târgoviște, Romania.
- Pehoiu G.; Murărescu O. (2009). Climate Change Impact on Environment and Health of the Population in Dâmbovița County, Romania, *Proceedings of the 2<sup>nd</sup> WSEAS International Conference on Climate Changes, Global Warming, Biological Problems* (CGB '09), ISSN:1790-5095, ISBN: 978-960-474-136-6, Morgan State University, Baltimore, USA, November 7-9, 2009.
- Pehoiu G.; Simion T.; Murărescu O.M. (2005). Climat urbain, et la pollution de l'air dans les villes industrielles. Etude de cas - La ville de Târgoviște (Roumanie). XVIIIe Colloque Internationale de Climatologie, Genova, 7-11 septembre 2005. In: *Climat urbain, ville et architecture*, ed. Gerardo Brancucci, pp. 39-42, Laboratoire de Géomorphologie Appliquée, Département Polis, Université de Gênes, Retrieved from <http://climato.ulg.ac.be/doc/AIC-table.pdf>.

- Pehoiu G. (2008). The impact of human activities on environmental quality in Dâmbovița county. In *Present Environment and Sustainable Development*, Vol. 2, pp. 283-296, „Alexandru Ioan Cuza” University, ISSN 1843-5971, Iași, Romania.
- Planul Local de Acțiune pentru Mediu al Județului Dâmbovița* (Local Plan of Action for Environment of Dâmbovița County), 2010, Târgoviște, Romania.
- Agencia pentru Protecția Mediului - Dâmbovița (Agency for Environmental Protection - Dâmbovița County), *Raport privind starea mediului în județul Dâmbovița* (Report regarding state of the environment in Dâmbovița County), 2000-2010, Târgoviște, Romania.



## **Air Pollution - Monitoring, Modelling, Health and Control**

Edited by Dr. Mukesh Khare

ISBN 978-953-51-0381-3

Hard cover, 254 pages

**Publisher** InTech

**Published online** 21, March, 2012

**Published in print edition** March, 2012

Air pollution has always been a trans-boundary environmental problem and a matter of global concern for past many years. High concentrations of air pollutants due to numerous anthropogenic activities influence the air quality. There are many books on this subject, but the one in front of you will probably help in filling the gaps existing in the area of air quality monitoring, modelling, exposure, health and control, and can be of great help to graduate students professionals and researchers. The book is divided in two volumes dealing with various monitoring techniques of air pollutants, their predictions and control. It also contains case studies describing the exposure and health implications of air pollutants on living biota in different countries across the globe.

### **How to reference**

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Pehoiu Gica and Murărescu Ovidiu (2012). Pollution and Air Quality in Târgoviște Municipality and Its Surroundings (Romania), Air Pollution - Monitoring, Modelling, Health and Control, Dr. Mukesh Khare (Ed.), ISBN: 978-953-51-0381-3, InTech, Available from: <http://www.intechopen.com/books/air-pollution-monitoring-modelling-health-and-control/air-quality-and-pollution-in-ta-rgovis-te-municipality-and-the-surrounding-area-romania->

**INTECH**  
open science | open minds

### **InTech Europe**

University Campus STeP Ri  
Slavka Krautzeka 83/A  
51000 Rijeka, Croatia  
Phone: +385 (51) 770 447  
Fax: +385 (51) 686 166  
[www.intechopen.com](http://www.intechopen.com)

### **InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821



© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen